



# *State-of-the-Art Practices in Stream Restoration*

*Development in Chattanooga:  
The Stormwater Perspective*  
*April, 2003*

# Fluvial Geomorphology



Branch of Science concerned with influence of Rivers and Streams on the formation of the Earth's surface

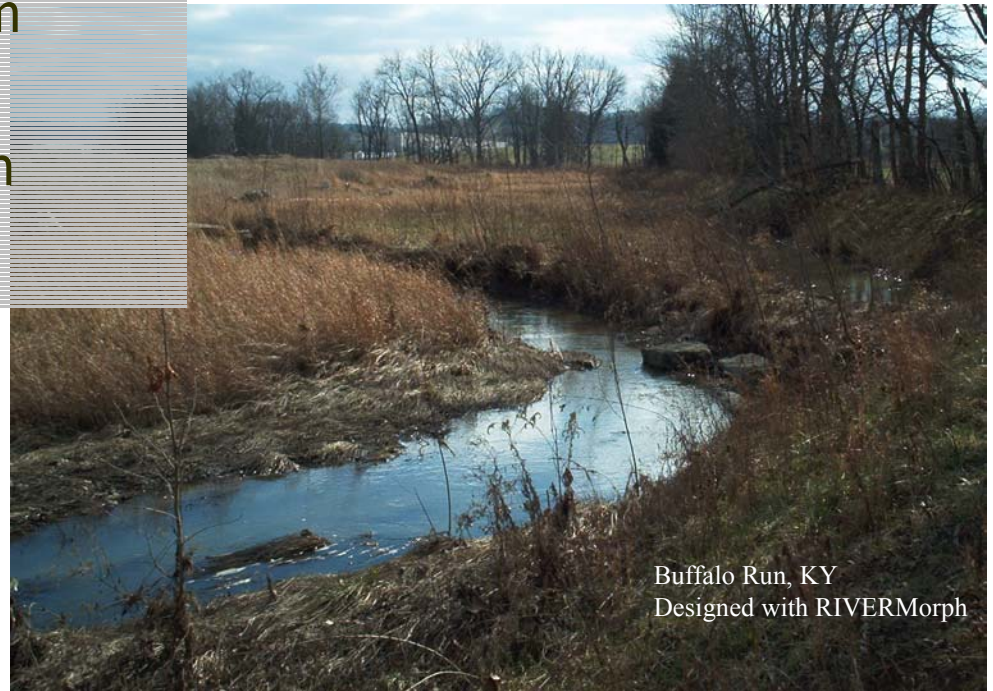
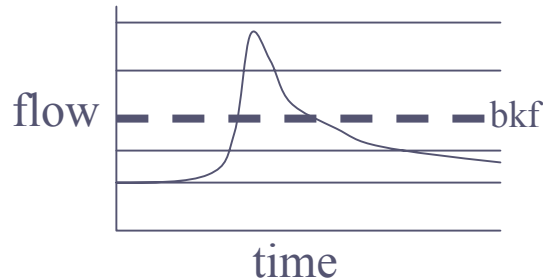
## **Governing Processes:**

- Erosion
- Sediment Transport
- Deposition



# Bankfull Discharge

- Controls Average, Long-Term Channel Form
- Corresponds to the Discharge that Channel Maintenance is Most Effective over the Long-Term
- Low Recurrence Interval
- Lower Recurrence Interval in Urban Watersheds



# Bankfull Indicators



- Flat, Depositional Surface Adjacent to Active Channel
- Height of Depositional Features (Point Bars)
- Change in Vegetation
- Slope or Topographic Breaks or Changes Along the Bank
- Change in Particle Size of Bed Materials



# Entrenchment Ratio (ER)

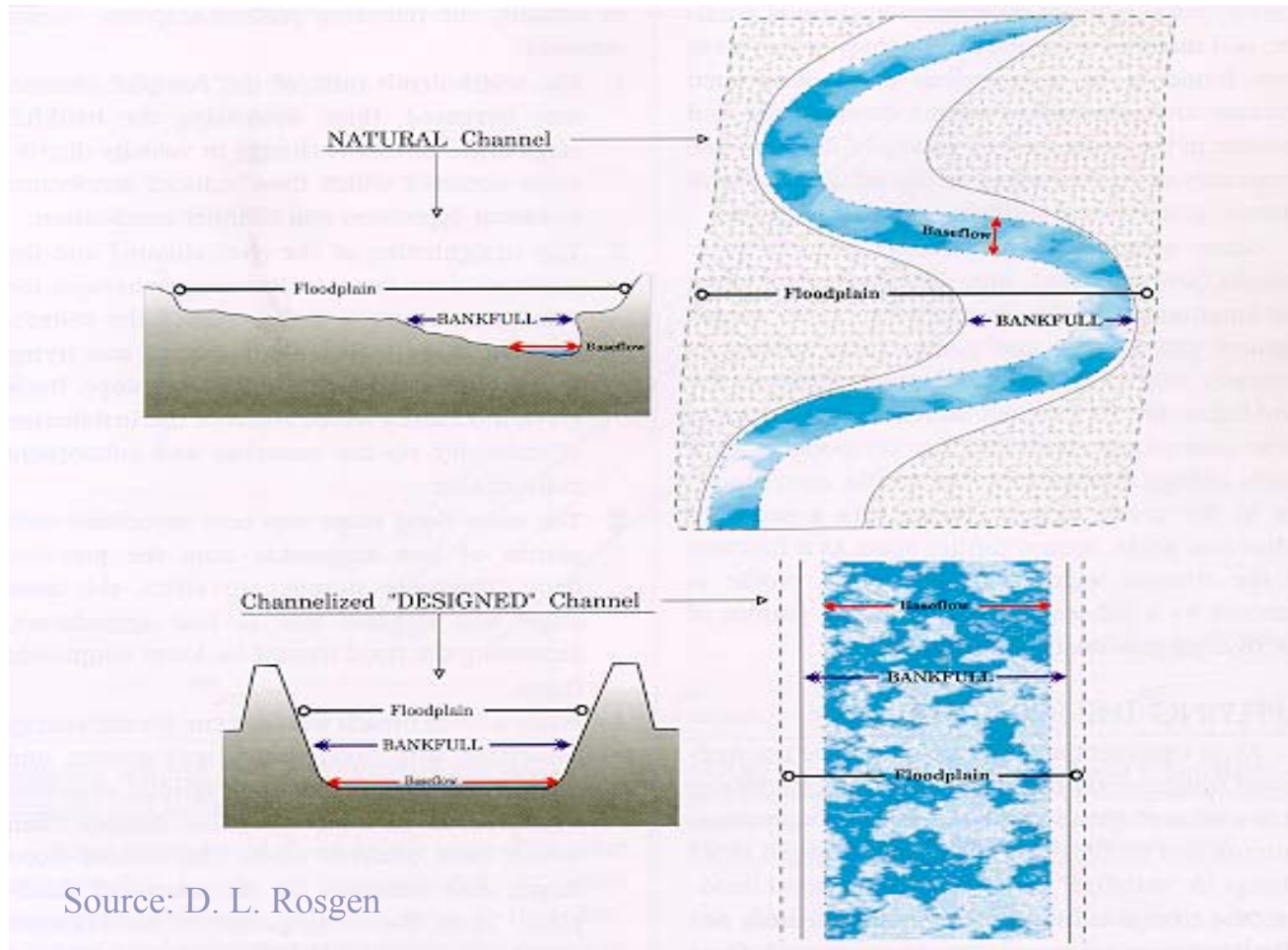


The Vertical Containment of the Stream or the Degree of Incision in the Valley Floor

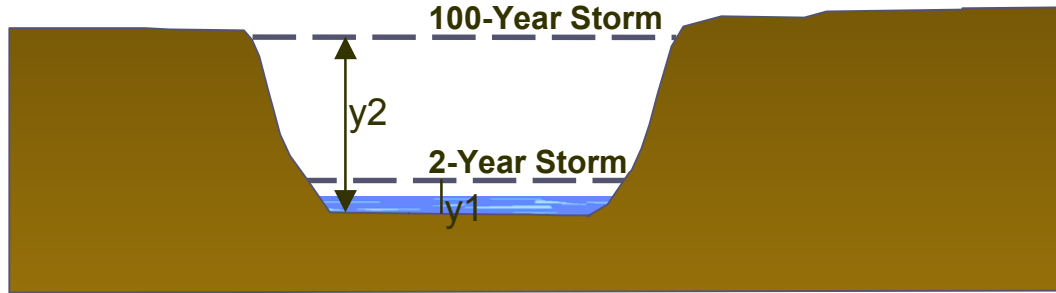
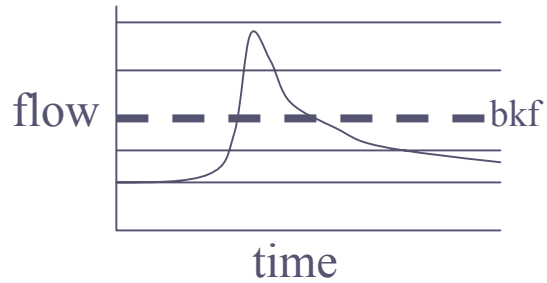
$$\text{Entrenchment Ratio} = \frac{\text{Width of Floodprone Area}}{\text{Width of Bankfull Channel}}$$

- Entrenched (Ratio < 1.4)
- Moderately Entrenched (1.4 - 2.2)
- Slightly Entrenched (Ratio > 2.2)

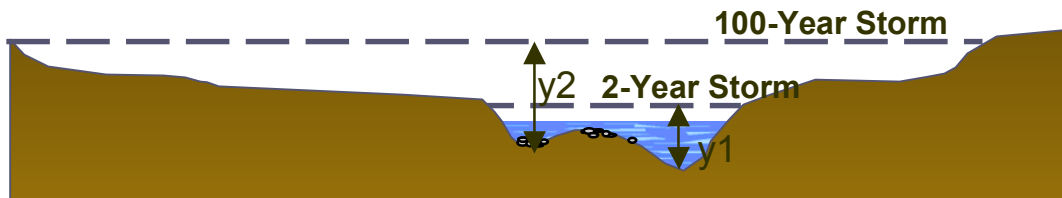
# Natural vs. Man-Made Channels



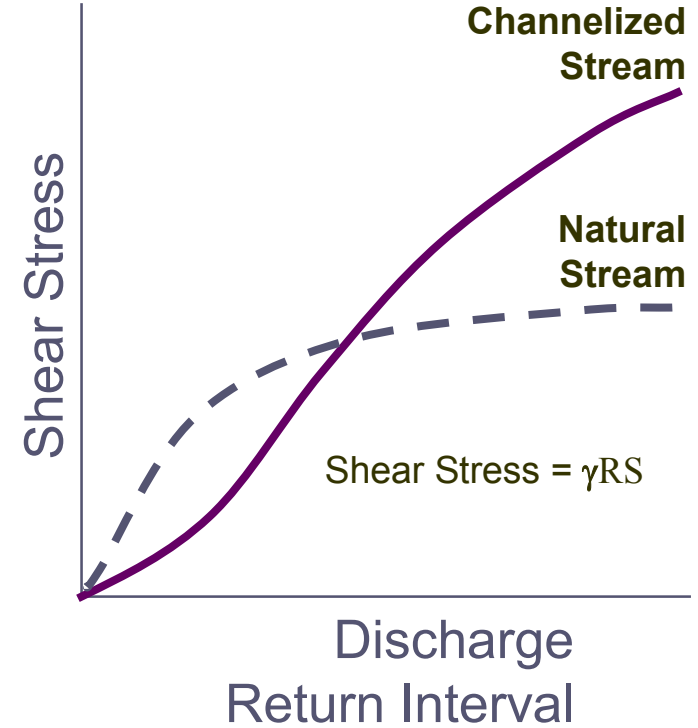
# Shear Stress



**Channelized Stream**



**Natural Stream**



# Differences



<b>CONCEPT</b>	<b>TRADITIONAL</b>	<b>GEOMORPHOLOGY</b>
Time	Short-term	Long-term
<b>Model</b>	<b>Theoretical</b>	<b>Field Measurement</b>
Water	Clear	Sediment Laden
<b>Spatial Scale</b>	<b>Reach</b>	<b>Watershed</b>
Boundary	Rigid	Mobile
<b>Maintenance</b>	<b>High</b>	<b>Sustainable</b>
Design Flow	100 yr.	Bankfull Flow
<b>Factor of Safety</b>	<b>Conservative</b>	<b>Balance of Forces</b>

# Natural Channel Design



Process by which new or re-constructed stream channels and their associated flood plain riparian systems are designed to be naturally functional, stable, healthy, productive and sustainable.

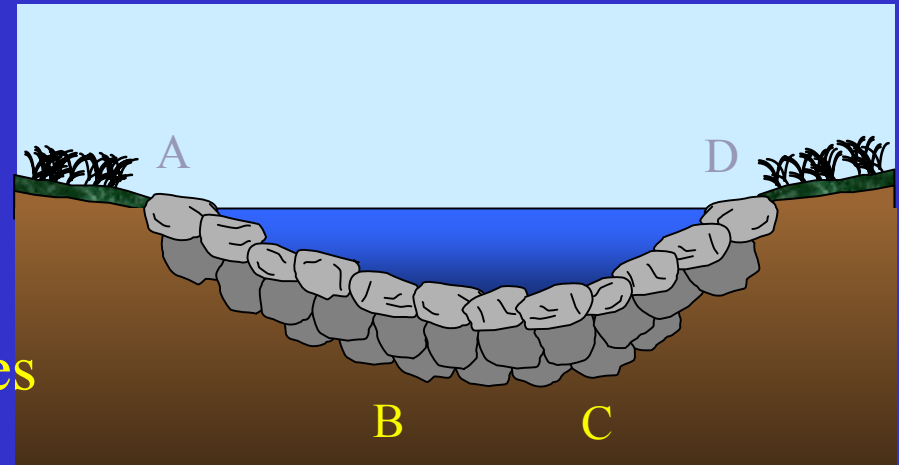
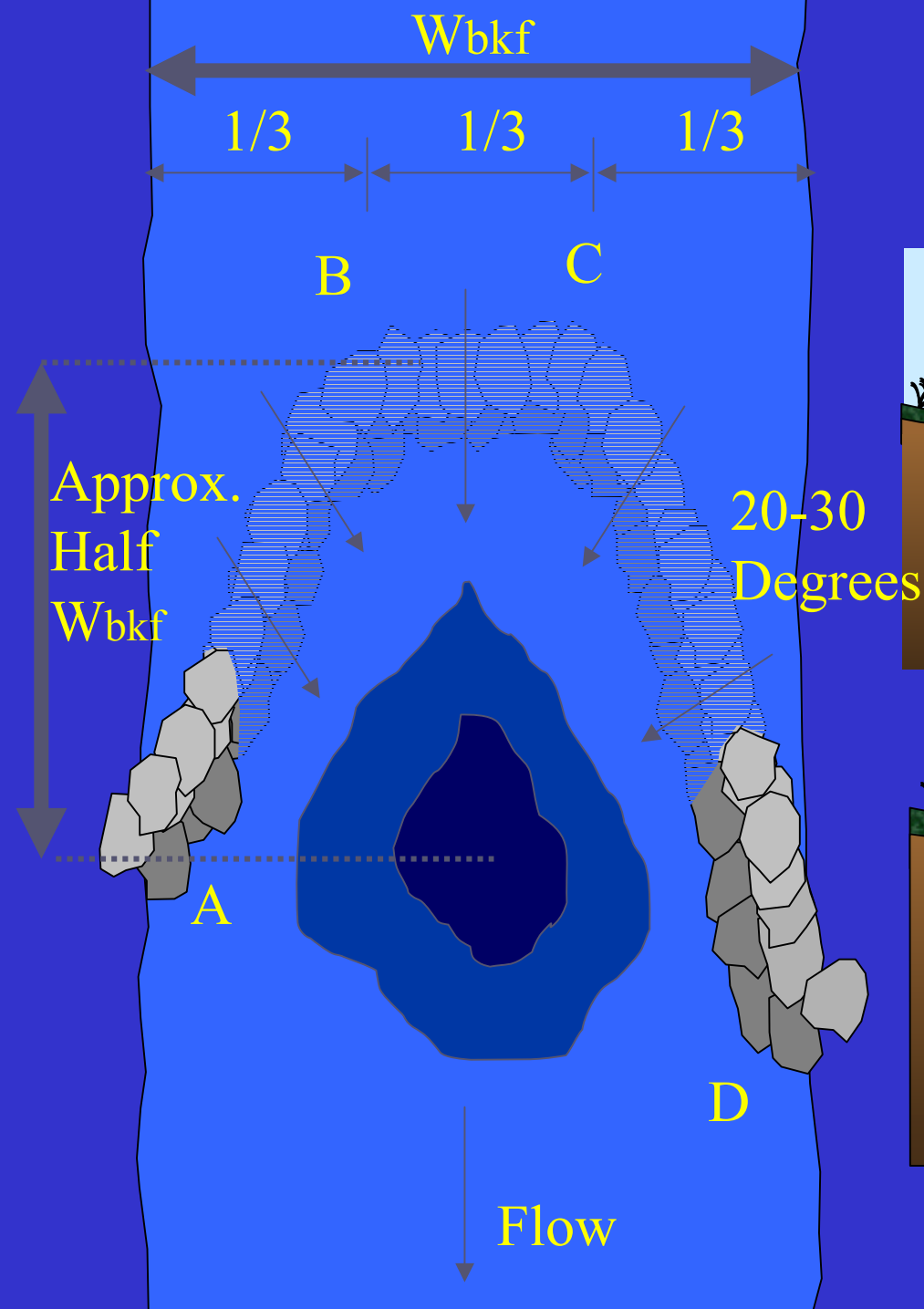


# Soil Bioengineering

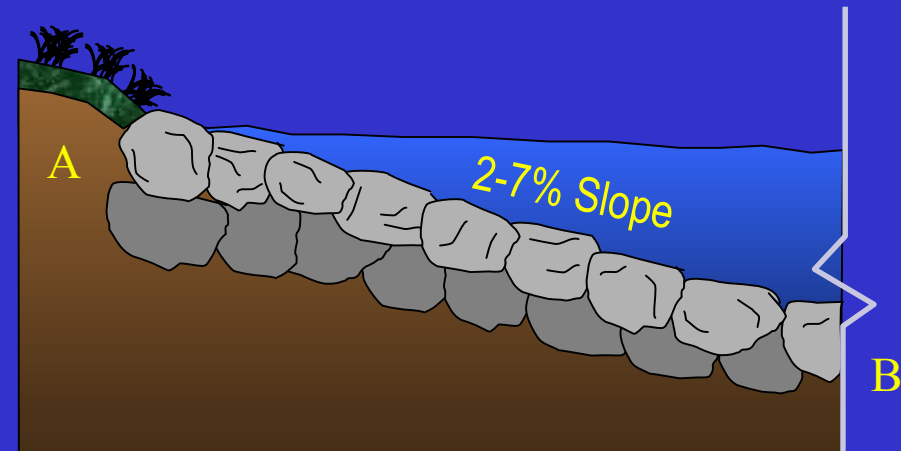
The Use of Living and Non-Living Materials to Provide Soil Reinforcement and Prevent Erosion



# Cross-Vane



Cross Section View



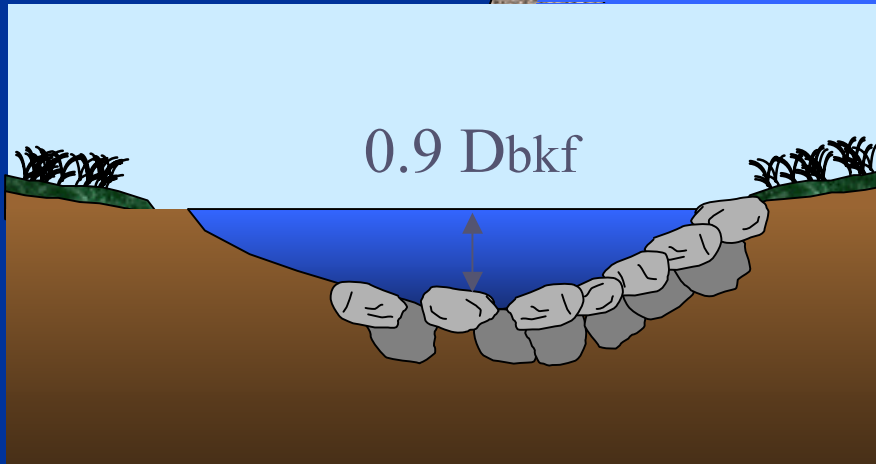
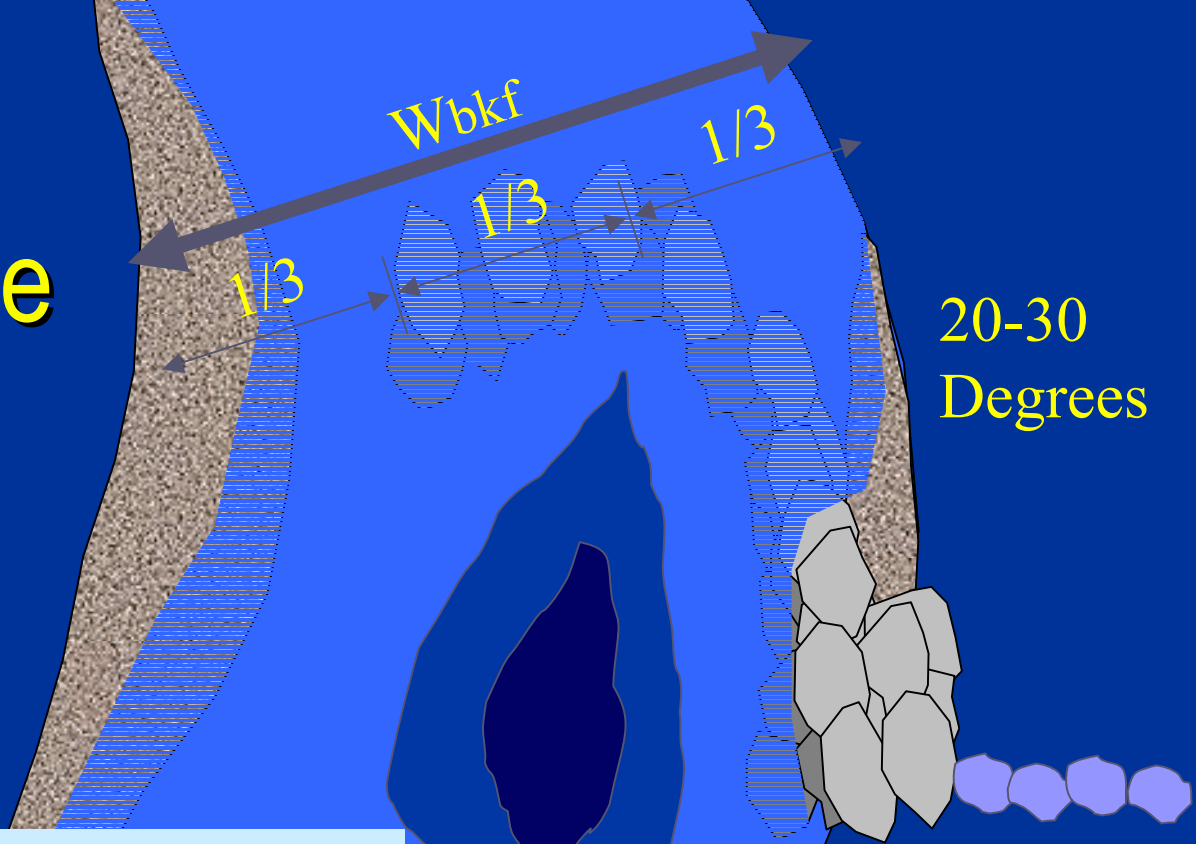
Longitudinal Profile

# Rio Blanco



# Bank Stabilization Structures

## J-Hook Vane



Cross Section View

# Rio Blanco







# Reference Reach Approach



- Stable Reference Stream in Same Hydro-physiographical Region
- Streams Exist in Dynamic State of Equilibrium
- Requires a Number of Geomorphic Measurements - Range of Dimensionless Ratios
- Applies to Streams where Upper Ranges of Depositional Particles Begin to Mobilize at Bankfull
- In Sand Bed Streams Additional Analytical Analyses is Necessary

Dimensionless Ratios and Ranges of Values



Dimension	Pattern	Profile	Hydraulics
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Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
B 4c	II	10.06	0.0035	112	3.1

Variable	Min	Ave	Max
Floodprone Width	31.56	35.21	38.86
Riffle Area	26.15	32.49	38.83
Riffle Max Depth	2.32	2.62	2.92
Riffle Mean Depth	1.27	1.52	1.76
Riffle Width	20.55	21.32	22.08
Pool Area	28.87	33.58	37.28
Max Pool Depth	2.50	2.85	3.12
Mean Pool Depth	2.14	2.35	2.54
Pool Width	12.30	14.31	15.89
Run Area	32.35	34.52	36.54
Max Run Depth	2.45	2.65	2.90
Mean Run Depth	2.04	2.10	2.22
Run Width	12.20	14.28	14.36
Glide Area	28.72	29.97	31.45
Max Glide Depth	2.21	2.45	2.58
Mean Glide Depth	1.95	2.13	2.23
Glide Width	12.05	14.06	14.25

Note: Maximum depths from this screen are saved to the database as the reach average values. Refer to the "Profile" tab for more options.

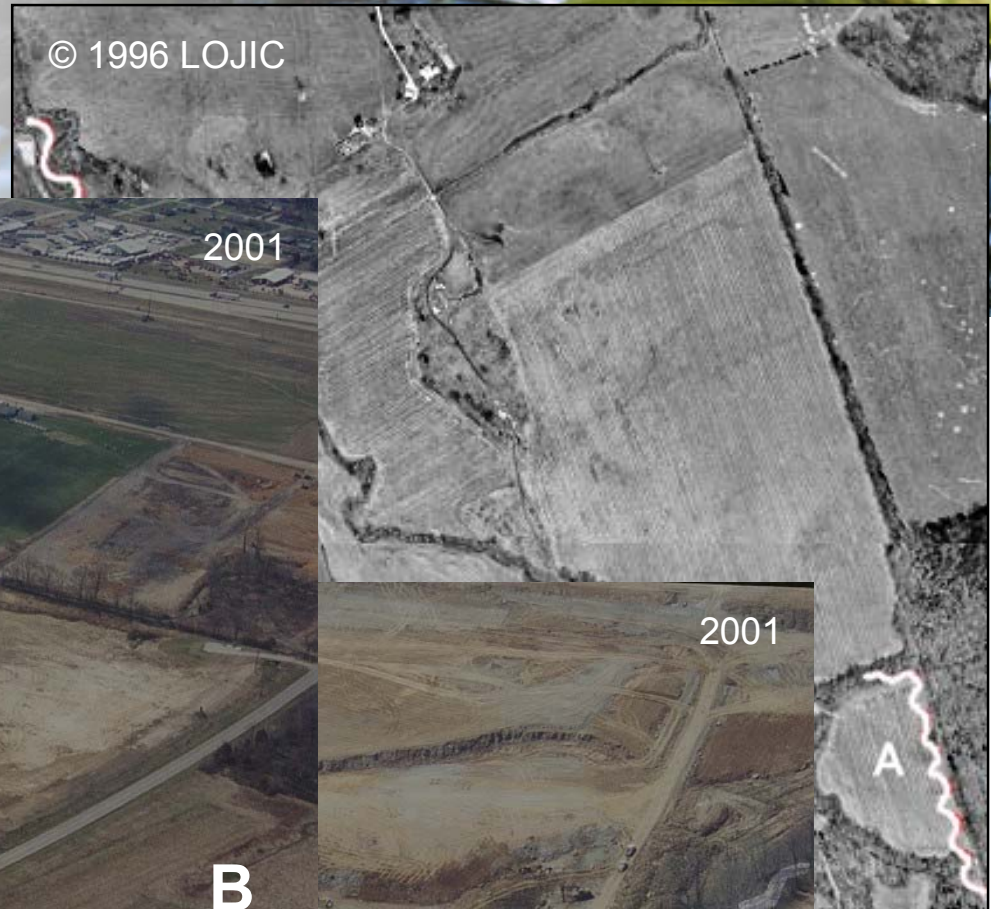
View as Actual Values

View as Dimensionless Ratios

# Buffalo Run Stream Restoration



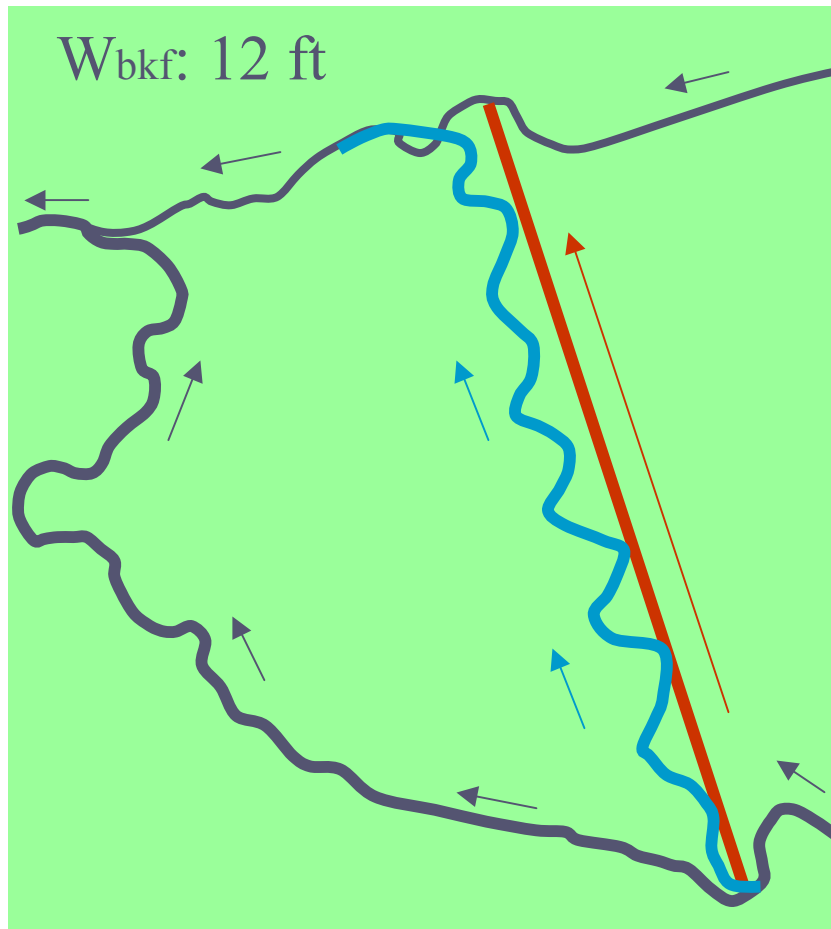
# Buffalo Run



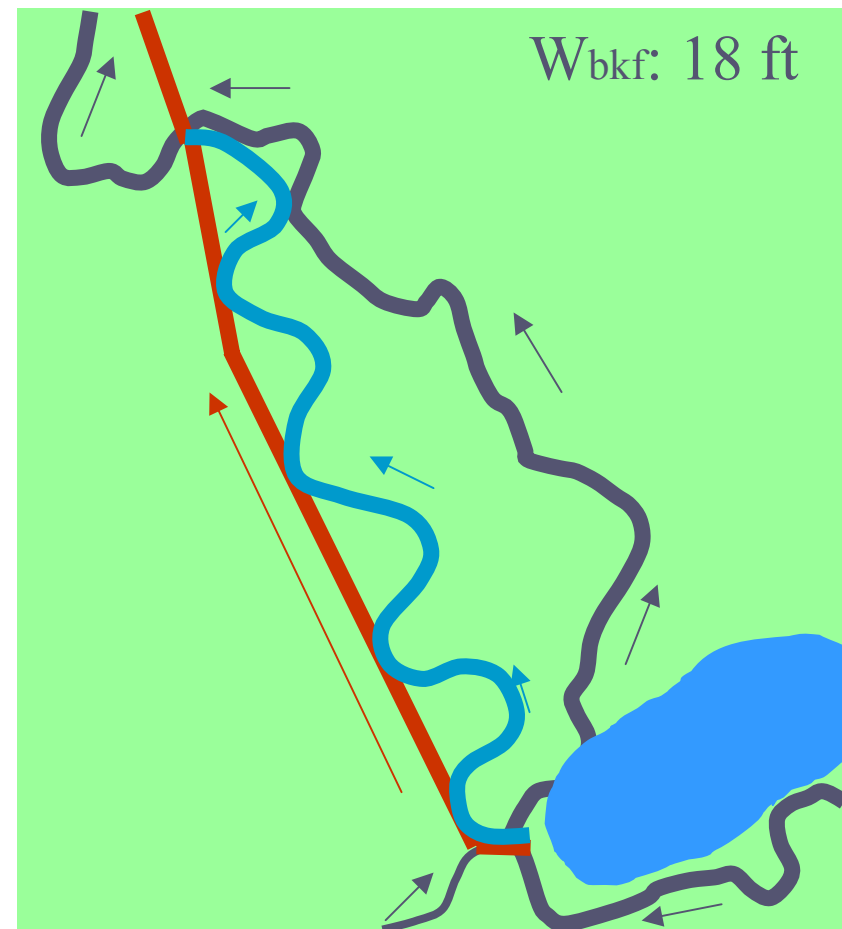
# Natural Channel Designs



Reach A (Upstream)

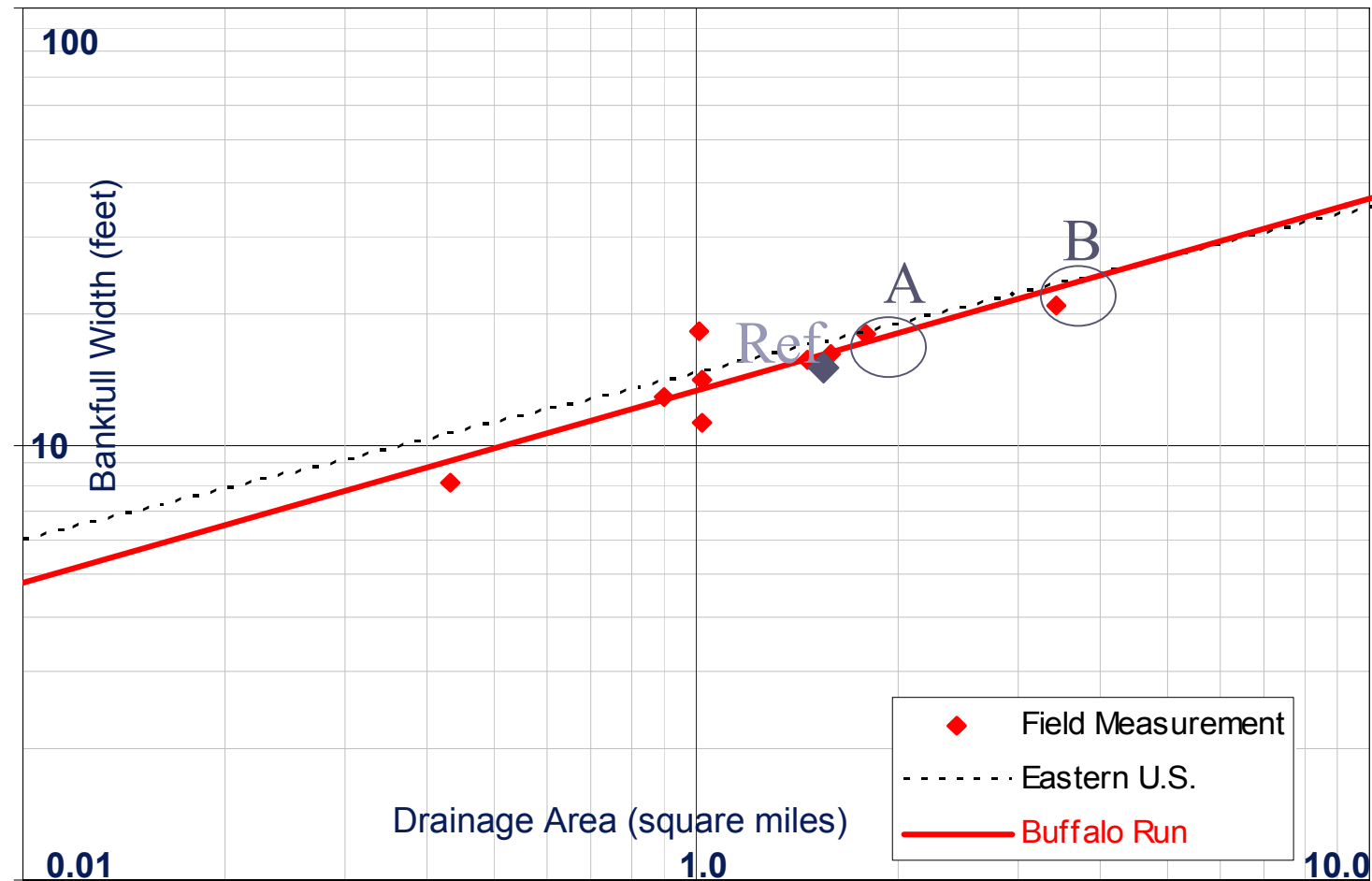


Reach B (Downstream)



# Design Processes

## Step 1: Watershed Analysis



# Design Process

## Reference Reach



**RIVERMorph 2.1 Professional**

Buffalo Run

Reference Reach | Boundary Conditions | Results | Plan View | Long Pro | Typical Sections

Report | Reset | Reload Dimensionless Ratios

Planform Geometry

Meander Wavelength (Lm)	113.81
Channel Length (Lc)	138.85
Sinuosity (K)	1.22
Radius of Curvature (Rc)	25.1
Bankfull Slope (Sbkf)	0.00246
Meander Belt Width (Wbkt)	38.48
Meander Width Ratio (MWR)	2.96

Riffle Geometry

Width to Depth Ratio (W/D)	12.03
Entrenchment Ratio (W/pa/Wbkf)	3.79
Floodprone Width (W/pa)	49.27
Bankfull Width (Wbkf)	13
Bankfull Mean Depth (Dbkf)	1.08

Riffle Hydraulics

Bankfull Velocity (Vbkf)	2.28
Bankfull Hydraulic Radius (HR)	0.93
Bankfull Shear Stress (Tbkf)	0.142
Required Roughness (n)	0.0308
Movable Particle Size	8.8

Sediment Transport Competency

D50 bed / D50 bar	3.361
Crit. Dim. Shear (1)	0.029
Depth Needed (1)	2.11
D1 bar / D50 bed	2.727
Crit. Dim. Shear (2)	0.0158
Depth Needed (2)	1.15
Min. Mean Depth	1.15

Rosen Stream Classification

REF. C4 NCD C4 IMP. C4

GIS | Regional Curves | Resistance Equations

Hand-drawn sketches of stream planform and cross-sections.

Wbkt {30...41}

MWR = 3

Rc/Wbkf = 2

Lm/Wbkf = 9

Wbkf/Dbkf = 12

# Boulder Structures





+ 3.6 fps

+ 11.4 fps

+ 2.2 fps

# Buffalo Run: Reach A

## Natural Channel Diversion

### C4 Stream Type



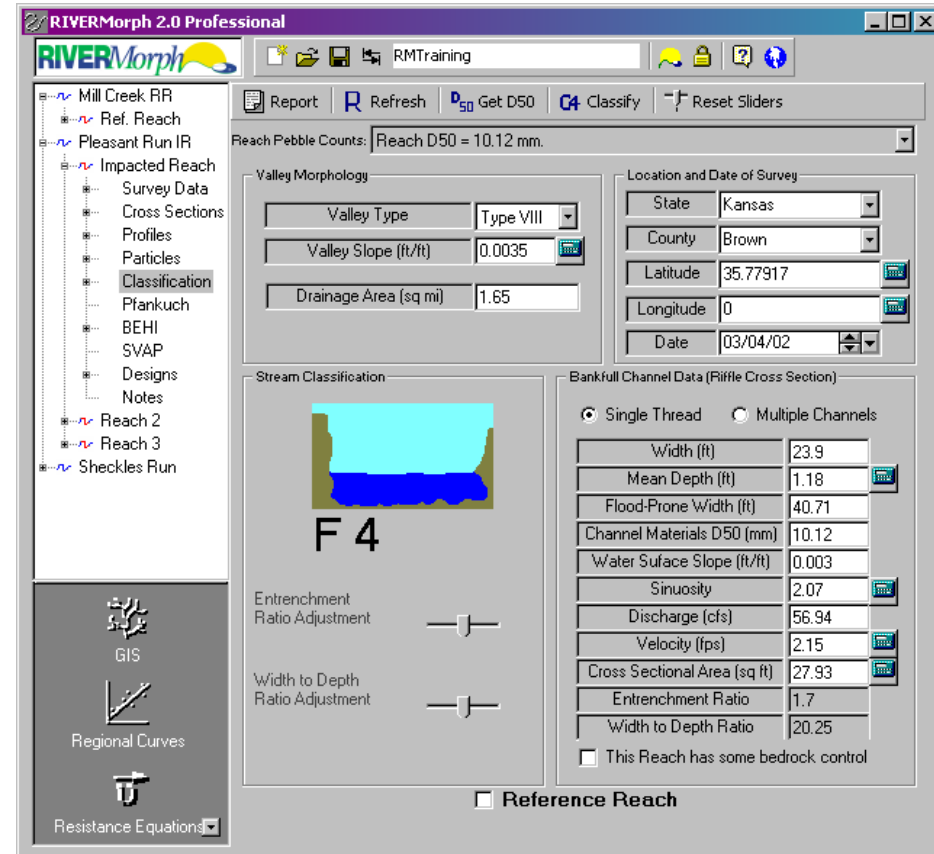


Buffalo Run: Reach B  
Restoration  
C6 Stream Type

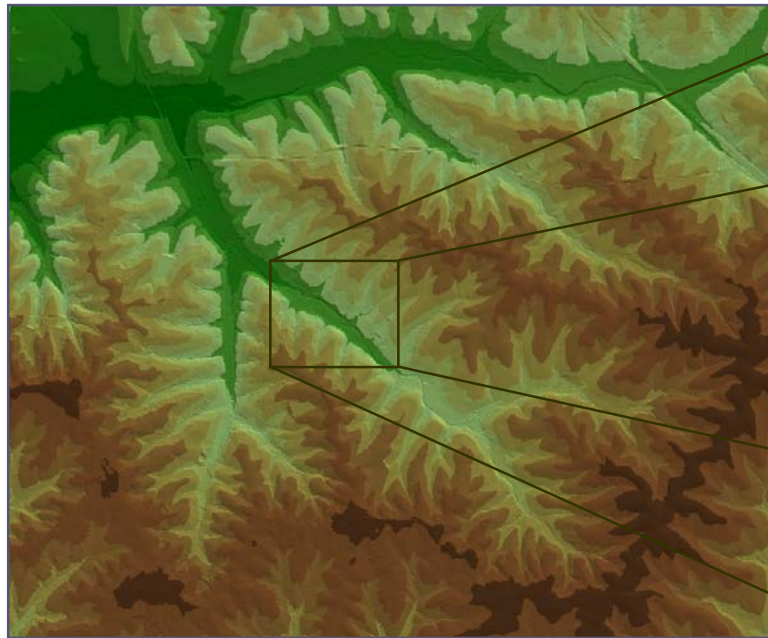
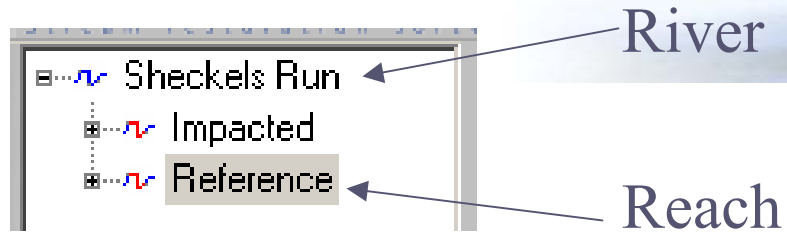
# Software Overview



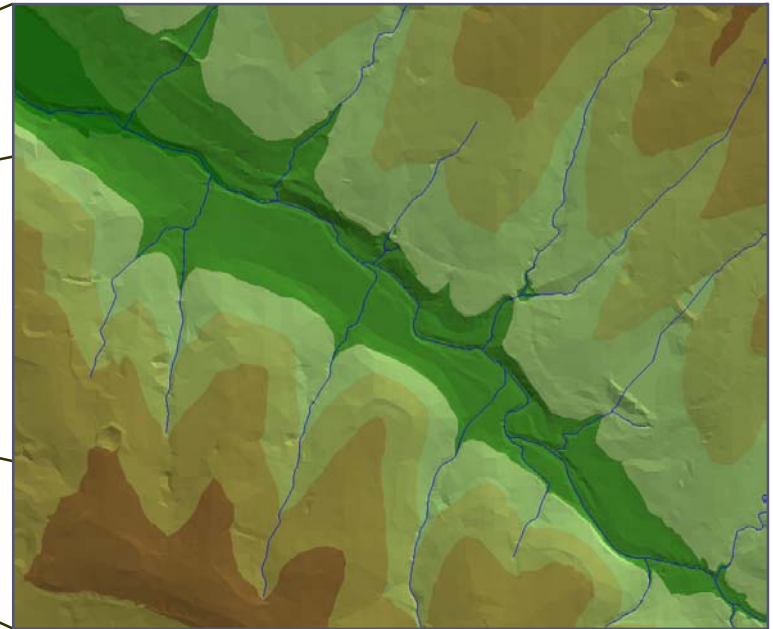
- Software Features an Intuitive Graphical User Interface
- All Data Stored in a Database
- Measurements/Processing of Data is Graphically Oriented
- Greatly Simplifies Processing of Geomorphic Data



# Rivers and Reaches



River Scale



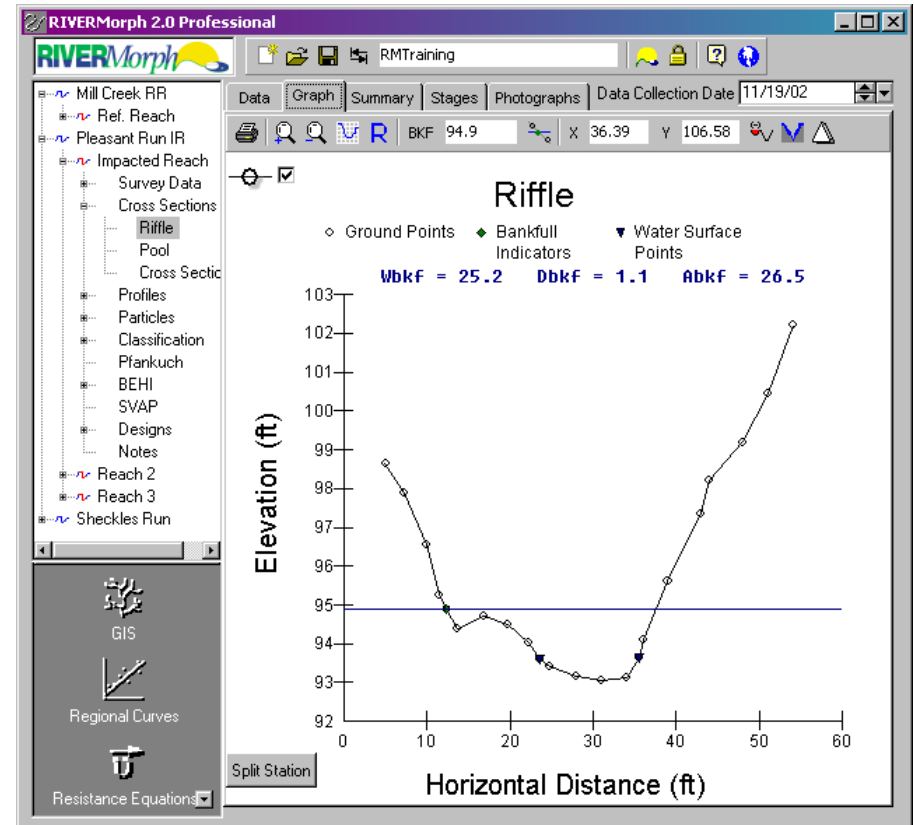
Reach Scale —  $(20 \text{ to } 30) \times W_{bkf}$

# RIVERMorph Components



## CHANNEL MEASUREMENT

- Survey Data (Differential & Total Station)
- Cross Sections
- Longitudinal Profile
- Particle Size Analyses (Pebble Count & Sieve Analysis)
- Stream Classification

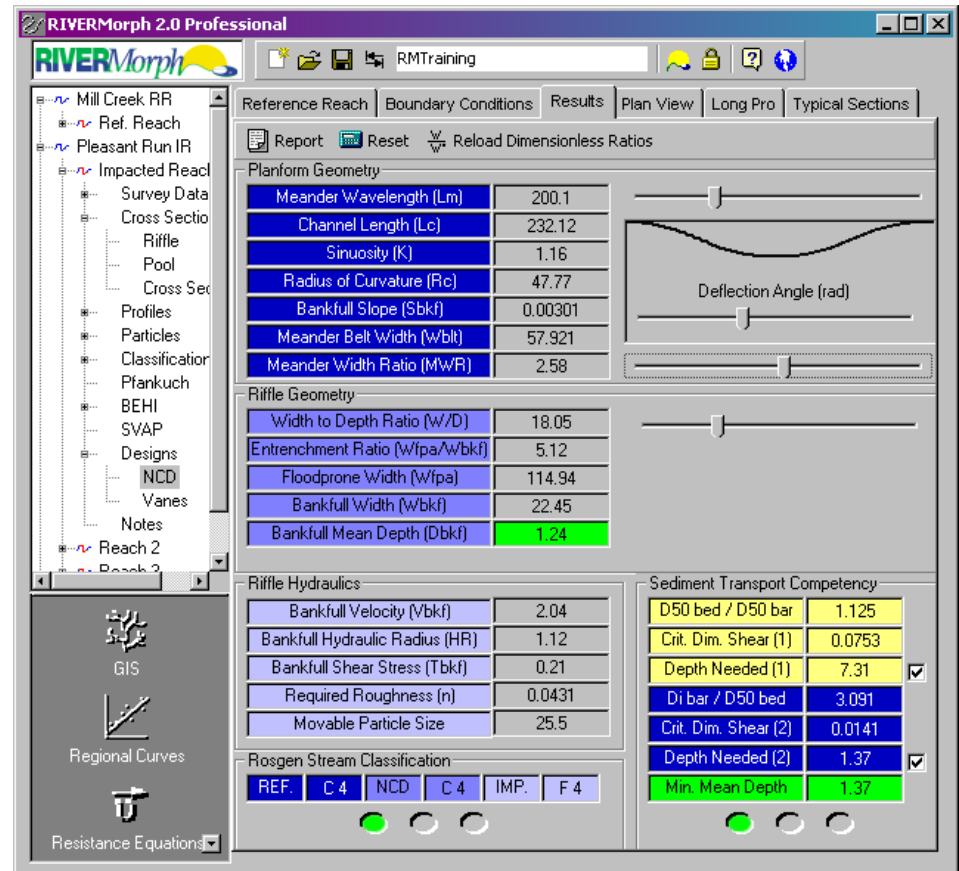


# RIVERMorph Components



## ANALYSES & DESIGN

- Pfankuch Channel Stability
- NRCS Stream Visual Assessment Protocol
- Natural Channel Design Using the Reference Reach Approach
- Vane Structures



# RIVERMorph Components



## CALCULATORS & TOOLS

- GIS
- Regional Curves
- Resistance Equations
- Regime Equations
- TR-55 Peak Flow
- Gage Analysis

**Resistance Equation Calculator**

Calculate Close

Manning Chezy Darcy-Weisbach Pipe Flow

Manning Roughness Coefficient (n)

Limerinos Cowan Stream Type Known

Mean Depth or Hydraulic Radius (ft)

Bed Material D84 (mm)

Manning's n:

Cross Sectional Area (sq ft)

Wetted Perimeter (ft)

Hydraulic Slope (ft/ft)

Velocity (fps):

Discharge (cfs):

$$U = \frac{C_m}{n} R^{2/3} S^{1/2}$$